ANNALS OF THE ORADEA UNIVERSITY
Fascicle of Management and Technological Engineering
ISSUE #1, MAY 2015, http://www.imtuoradea.ro/auo.fmte/

RESEARCH ON SEQUENTIAL SPEED DRIVING OF THE PRESSURE WAVE COMPRESSORS

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***Abstract*—** Pressure wave compressor is one of the efficient compressors that can supercharged internal combustion engines. In this compressor, the intake air interacts directly with the exhaust gases in the rotor channels. Thus, the intake air is directly compressed by the exhaust gases, the role of the rotor is that of distribution of the exhaust gas and of the intake air. For a certain type of compressor, the value of the supercharging pressure varies with the value of exhaust gas pressure and with the driving speed of the compressor. Currently, the pressure wave compressor is driven by the crankshaft. However, this solution limits the efficiency of the compressor because the driving speed depends only on the speed of the engine and not on its load. In this context, this paper highlights another driving solution that streamlines the pressure wave compressor, without particularly increasing the cost of the process of supercharging.

***Keywords*—**engine, pressure wave compressor, speed, supercharging.

I. Introduction

ONE of the compressors used in the supercharging of internal combustion engine is the pressure wave compressor [1]. The two main variants of this compressor are Comprex and Hyprex. The first is destined to the supercharging of compression ignition engines, and the second to the supercharging of spark ignition engines.

In the pressure wave compressor, the air is compressed directly by the exhaust gases. So, the supercharging pressure depends directly on the exhaust gas pressure. Another significant influence on the supercharging pressure is the driving speed of the compressor. There is a strong dependence between the value of the speed compressor and the time available for the development of the process of compressing air.

As in Fig. 1., it can be claimed that the effectiveness of a certain pressure wave compressor depends significantly on how the two parameters are correlated: the pressure of the exhaust gases and the driving speed.

The fuel economy and environmental performances of the internal combustion engines must be improved [2], [3]. A solution to improve the internal combustion engines is to increase supercharging pressure, through by increasing the efficiency supercharging compressors [4].

Currently, on vehicles, the pressure wave compressor is driven by the crankshaft. But experimental research carried out on the test bench have shown the fact that this driving solution limits the efficiency of the pressure wave compressor [5].

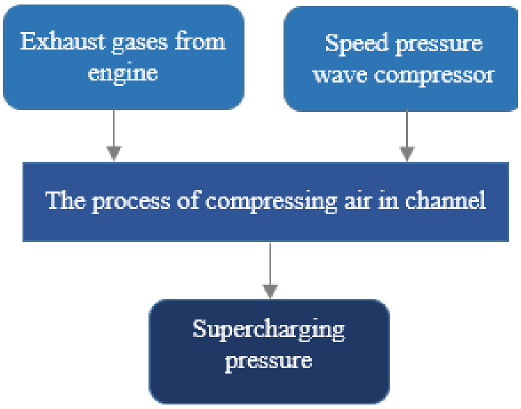

Fig.1. Influences on supercharging pressure

The compressor operates with a high efficiency when it is driven at a speed which is not proportional to the one of the supercharged engine.

An improving solution of the pressure wave compressor is to have it driven by an electric motor at a variable speed. Thus, for each operating mode of the internal combustion engine, the compressor can be driven at the speed at which a satisfactory value of supercharging pressure is obtained.

In this solution, the wide variety of speeds at which the compressor should be driven, requires an electronic control system of the electric motor by which to vary the speed of the electric motor. Therefore, the supercharging process is achieved at a higher cost compared with its conventional driving, from the crankshaft.

In this context, this paper aims at highlighting another effective solution for driving that does not particularly increase the cost of the turbocharging process, namely: sequential speed driving of the pressure wave compressor.

II. Compressing Air in Pressure Wave Compressors

In pressure wave compressors the transfer of energy from the exhaust gas to the intake air is made directly. The interaction between the exhaust gas and the intake air takes place inside the channels of the rotor of the pressure wave compressor.

For example, in the case of the Comprex type pressure wave compressor, CX-93 model, the rotor has 68 longitudinal channels ordered in two rows.

As in Fig. 2., in a channel of the rotor, the functional cycle begins with the entrance of fresh air in the channel trough air inlet port (4). By the rotation of the rotor, the exhaust gases enter the channel trough gases inlet port (1). The fresh air begins to be compressed by the advancement of the interface exhaust gases – intake air and shock wave [7]. The functional cycle ends by emptying the channel rotor of exhaust gases trough gases outlet port (2). The compressed air is evacuated trough air outlet port (3).

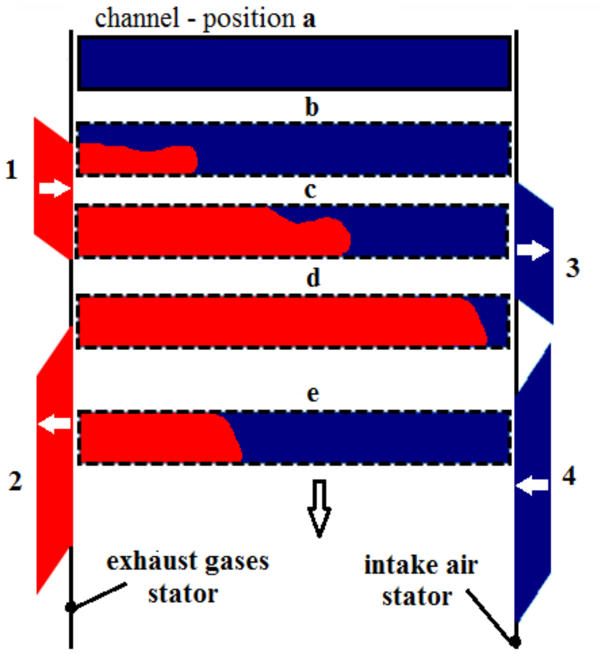

Fig. 2. Various positions of a channel – pressure wave compressor.

Basically the rotor of the compressor is designed to distribute the exhaust gases and the air. The channels of the rotor making the connection between the stator through which the exhaust gases and the stator through which the intake air cross.

Each of the two stators comprises two inlet ports and two outlet ports. Thus, after a complete rotation of the rotor, each channel will come in front of the inlet and outlet ports twice. This solution, which ensures the running of the two-cycle operation at a single speed rotor reduces to half the speed at which the pressure wave compressors function.

Because the intake air compression is carried out by the exhaust gases, the energy necessary to the driving of the compressor is reduced. According to [6], in some experimental research the necessary power to the driving of the compressor has not exceeded 350 (W). This reduced value of energy consumption from the engine is due to the fact that the two inlet ports are inclined (Fig. 3.), so that when the exhaust gases enter the channel they rotate the rotor.

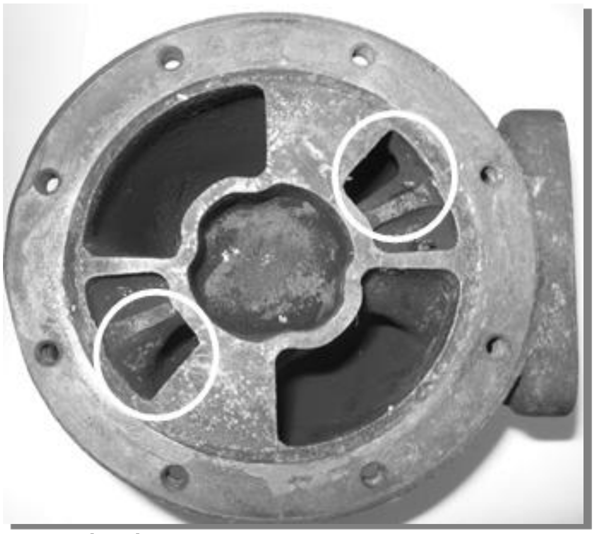

Fig. 3. The exhaust gases stator – pressure wave compressor, type Comprex, model CX-93.

It can be claimed that a high quality of the compression process is achieved when the supercharging pressure has a value close to the pressure of exhaust gases (the pressures equalize). This requires the rotor to be driven at a speed allowing a complete deployment of the compression process of the fresh air in channel. It is conceivable that the compression process took place completely if the exhaust gases crossed the entire length of the channel [7].

III. Correlation Between Speed Pressure Wave Compressor and Exhaust Gas Pressure

The exhaust gases move in the channels of the rotor at a speed proportional to their pressure. Therefore, an increase in the dynamics pressure of the exhaust gases requires a shorter duration of the intake air compression process carried out in the channels of the rotor, because the speed of movement of the interface exhaust gases- air is higher [8], [9].

Therefore, it can be claimed that with the increase of the pressure of exhaust gases, the driving speed of the compressor should increase.

During the operation of the internal combustion engines at a given speed, the exhaust gas pressure varies proportionally to the load. Therefore, the driving speed of the compressor should not be dependent only on the speed of the engine (as it happens in the case of the crankshaft driving), but the engine load must be taken into account (as is the case in the driving at a variable speed from an electric motor).

According to [9], the supercharging pressure is strongly influenced by the pressure of the exhaust gases. Also, according to [5], the pressure wave compressor functions with high efficiency when driven at speeds that are not proportional to those of the supercharged engine. In comparison with the supercharging with turbocharger, higher performance was obtained by the driving of the pressure wave compressor at a variable speed from an electric motor [4], [10].

Experimental results have shown that by varying the pressure wave compressor speed of a Comprex CX-93 type by 70%, a variance of up to 10% supercharging pressure was mainly obtained, with point increases of up to 16% [11].

All these aspects support the fact that for a certain model of compressor the main influence on the supercharging pressure is represented by the pressure of the exhaust gases. Therefore, the driving of the training pressure wave compressor with sequential speed, can represent a viable solution to supercharge the internal combustion engines. This solution is of interest especially if it is intended to optimize the efficiency of the pressure wave compressor at the cost of the supercharging process.

IV. Sequential Speed Driving of the Pressure Wave Compressor

The principle of the driving solution with sequential speed of the pressure wave compressors is similar to that of the driving solution at variable speed [5]. The difference between the two solutions lies in the fact that, after the establishment of optimal speed at which the compressor should be driven, a selection is made of the speeds at which the pressure wave compressor will be driven (TABLE I).

TABLE I
Compressor Speed Selection in the Sequential Speed Driving Solution

Engine parameters		Driving at variable speed	Driving at sequential speed
Load (l)	Speed (s)	Speed drive compressor (s_C)	
l_1	s_1	$s_{C1.1}$	s_{C1} average speed of: $s_{C1.1}, s_{C1.2}, \ldots, s_{C1.n}$
	s_2	$s_{C1.2}$	
	s_3	$s_{C1.3}$	
	⋮	⋮	
	s_n	$s_{C1.n}$	
l_2	s_1	$s_{C2.1}$	s_{C2} average speed of: $s_{C2.1}, s_{C2.2}, \ldots, s_{C2.n}$
	s_2	$s_{C2.2}$	
	s_3	$s_{C2.3}$	
	⋮	⋮	
	s_n	$s_{C2.n}$	
⋮	⋮	⋮	⋮

The entire range of values within which the driving speed of the compressor varies will be divided into 2-3 parts. Thus, 2-3 limited domains of driving speed of the compressor will result.

For each domain an average speed will be established by which the compressor will be driven. In this way, by reducing the speed at which the compressor will operate, the electronic system for the variation of the driving speed will simplify.

In the follow-up the advantages of the driving solution with a sequential speed of the pressure wave compressor will be presented in relation to the one when the driving is made by the crankshaft.

V. Experimental Results

Experimental researches were conducted on a compression ignition engine. It is a four-cylinder, supercharged and direct injection engine. During research the engine was equipped with a Comprex type pressure wave compressor, model CX-93.

The CX-93 Comprex type compressor was driven at a speed proportional to the engine speed the multiplication ratio of the speed is of value 7.

Another stage of the research consisted of supercharging the Comprex driven by a variable speed from an electric motor. From the optimal speeds, two driving speeds were established at which the compressor should be trained: 11000 (rpm) and 14000 (rpm).

As a result of experimental research that have been obtained show the efficiency of the pressure wave compressor within the two driving solutions.

Fig. 4. presents the increase of the supercharging pressure due to the driving of the sequential speed compressor compared with the solution of the crankshaft driving.

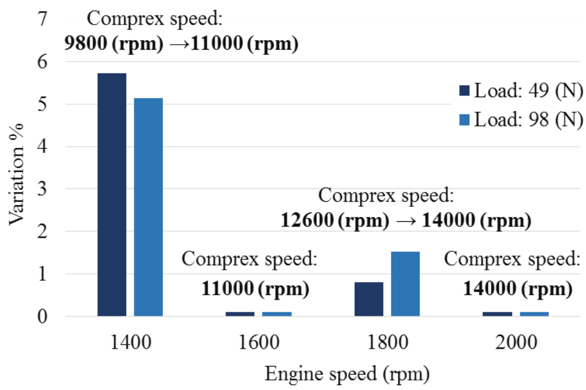

Fig. 4. The variation of the supercharging pressure at various speeds and engine loads.

Fig. 5. shows the influence of the driving solution of the sequential speed compressor on the maximum pressure in cylinders. The reference values are those obtained while driving the compressor at a proportional speed to the one of the crankshaft, the multiplication ratio is value 7.

These experimental results confirm that the solution of the crankshaft driving reduces the performance of the pressure wave compressor.

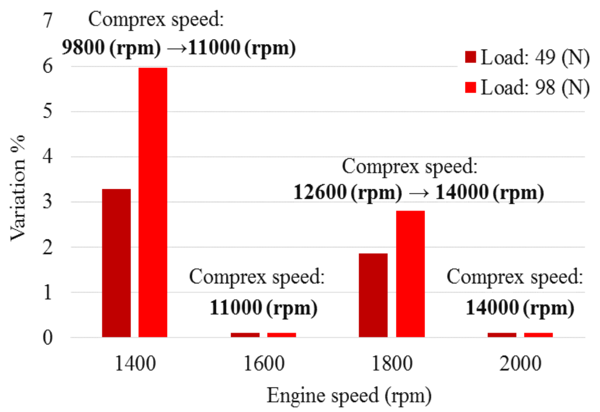

Fig. 5. Increased on the maximum pressure in cylinders, at the engine equipped with a pressure wave compressor driven at a sequential speed.

In general, the pressure wave compressor driven at a sequential speed ensures a higher level of the supercharging pressure. With the supercharging pressure increases the maximum pressure in cylinders.

At 1600 (rpm) and 1800 (rpm) speeds of the engine, for both driving solutions, the compressor is driven at a speed almost identical that is why the variation of the presented parameters is insignificant.

VI. Conclusions

While driving the pressure wave compressor from the crankshaft the multiplication ratio of the compressor's speed is limited by the domain of speed at which the engine operates and by the maximum speed of the compressor.

The solution of the driving from the electric motor with sequential speed compressor facilitates the positioning of the compressor on the engine, compared with the driving solution from the crankshaft.

The energy necessary to the driving of the pressure wave compressor is reduced, so that it is possible to use a small electric motor.

By the driving at a sequential speed, the performance of the compressor improves and implicitly those of the supercharged engine, without significantly increasing the cost of the supercharging process.

Acknowledgment

1. This paper is supported by the Sectoral Operational Programme Human Resources Development (SOP HRD), financed from the European Social Fund and by the Romanian Government under the project number POSDRU/159/1.5/S/134378.

2. We hereby aknowledge the structural founds project PRO-DD (POS-CCE, O.2.2.1., ID 123, SMIS 2637, ctr. No 11/2009) for providing the infrastructure used in this work.

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